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Media Related Requirements for Communication Services in a Distributed Multimedia Environment

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Abstract

For distributed multimedia applications adequate communication services have to be designed. Based on high speed networks, new transport services must cope with the quality of service requirements for the various media and support the higher level services for group control and synchronization. At the upper layers, services for distribution, group management, presentation, synchronization and access control are needed. In this paper, we propose an object-based model which depends on the type of media to be processed. The object definition contains a list of attribute specifications for all layers of the communication system. The applications are liberated from communication details, distribution, network architectures and host environments are transparent.

1. Introduction

New developments in workstation technologies have resulted in the ability of processing multiple media including audio and video by a computer [24]. Therefore, products based on local multimedia systems in various application areas like presentation and education are already available. The progress in communication technologies will provide LANs and MANs with dramatically increased bandwidth with more than 100 Mbps, more reliability and capable of handling different types of traffic. High speed broadband communication will also become the next generation of telecommunication networks. This evolution in communications allows for the integration of data, audio and full-motion video within a distributed system. Many application areas including interactive computer supported cooperative work (CSCW), see also [1; 4; 8], will make use of these services.

As the communication patterns and load depends heavily on the type of media being processed and transferred, the integration of various media implies new challenges to user interfaces, database, operating and communication systems. Concerning communication aspects of distributed multimedia systems systems, not only lower layer protocols for high speed networks are required, but also protocols in the upper layers are necessary to support the new applications and their efficient development. These services encompass the aspects of distribution, presentation, security, access control and synchronization properties of media streams. Some services are related to multimedia documents including models for their structure, presentation, representation and manipulation [21; 15].

In the following section communication issues like the quality of service, synchronization and multicast are discussed from the media specific point of view. Subsequently our communication model is derived. Within the application services an example is discussed and the notion of communication channels is introduced. In the final part of the paper the DiME project and th[e] conclusion is presented.

2. Some Communication Issues for Multimedia Data Transfer

Current transport services for data communications in LAN[s] are mainly based on packet switching techniques. Argument[s] for using this technology are derived from the bursty, asyn[chronous] type of traffic, where multiplexing of packets is con[venient]. Wide area networks (WANs) were due to their origi[n] from telecommunication services mostly line switched, bu[t] since 1987, B-ISDN as the new WAN service has moved fro[m] a more circuit switched environment (STM) towards asyn[chronous] data transmission (ATM). For audio and vide[o] communication isochronous data transmission via circu[it] switched networks is the original choice, but recent project[s] have shown that packet switching can also be feasible for suc[h] data streams [9; 11].

To satisfy the communication needs of the upcoming mult[i]media applications, the well known layered communication structure of the ISO/OSI model has to be enhanced. The OS[I] transport system (TS) has to support new data types for trans[mission], requiring more elaborated quality of services of th[e] TS to specify them. Additionally, applications require a mov[e] from communication links to enhanced communication struc[tures] like group communication with dynamically varying pa[r]ticipants as well as audio/video many-to-man[y] communications with all the problems of controlling suc[h] isochronous data streams on an asynchronous network be[tween] different sources and sinks. Therefore, the commun[i]cation system must become more "intelligent" and integra[te] techniques for both isochronous and asynchronous data tran[s]fer. For example, a multimedia applications wants to request [a] video link between specified multimedia objects but not strug[gle] with maintaining complex connection trees or synchron[i]zation control. More generally spoken, it is necessary to mov[e] from a connection oriented view of communication specifi[ed] by traffic parameters to a view on communication as a servic[e] requested by the applications via service selection.

To provide applications with such communication services, th[e] gap between connection oriented communication and mult[i]media communication services has to be filled at different leve[ls] of the communication architectures. The TS must support ad[]ditional quality of service parameters concerning simple con[]nections between two end points, and must provide bas[ic] functionality for higher layers to realize the more complex tas[k] of group communications, dynamic changes and synchroniza[]tion of data streams for isochronous services. These two are[as] are described in the next sections.

2.1 Quality of Service

Distributed multimedia applications generate communication traffic with very different characteristics and have distinct requirements in terms of services which must be covered by the TS. For distributed multimedia applications CCITT [3] has defined five services classes: conversational services, messaging services, retrieval services, distribution services and collection services. Each service class has different communication service requirements. The Quality of Service (QOS) required from the TS will get a new dimension since it depends on the type of data to be transmitted [12] and the application service class. It comprises the maximal delay, the bandwidth, the reliability criteria, the error handling, the multicast and the synchronization properties. The TS layer should provide mechanisms for the applications to request the QOS they need and to specify any routing constraints they may have. The QOS requirements towards the TS are moving from a static homogeneous policy to a dynamic heterogeneous one allowing for negotiation of the QOS.

Real-time interactive applications like a conference including voice or video rely on a ***maximal end-to-end delay***. A voice dialog typically should not exceed a 500 ms delay. The maximal delay requirement is certainly media and sometimes also application dependent. For a distribution of video data originated from a formal presentation given in some auditorium the end-to-end delay may be 2 seconds for example. The data packets to be transmitted from sender to receiver in real-time must be transferred with a maximal (better a constant) delay, otherwise they become useless. The actual data rate depends on the media, coding and packet switching technique used.

To cope with the increased ***bandwidth*** of the networks and to support multimedia communication protocols with minimized processing overhead, so called light-weight or paper-weight protocols are needed [10]. The throughput required for a medium like video depends on the coding scheme applied to the data stream. Uncompressed digital video signals according to the substandard 2 of CCIR 601 demand 135×10^6bit/s = 16,093 MB/s (luminance has 10,125 Mhz and chrominance 3,375 Mhz bandwidth). Symmetrical DPCM compression with 3 bit/sample leads to 29,611 MB/s. Video coding in DVI does not exceed 153,6 kByte/s. Audio data rates cover the whole range between about 16 kBit/s for voice coding for mobile radio to 176,4 kByte/sec for CD-Digital Audio.

The usage of compression techniques has impacts on the ***reliability criteria*** which are used to establish a communication channel. Uncompressed data video streams may tolerate bit errors, whereas DPCM compressed data relays on low bit error rate. On the other side, the transfer of text presumes a reliable error-free service. The tolerable image communication bit error rate depends also on the applications demands: X-Ray image transfer may have the same requirements as text transfer, whereas a FAX-image (class 1-3) may tolerate some bit errors.

A connection between two end points on a specific route may involve intermediate networks with distinct protocol semantics connected via gateways. In this case, the TS in the gateway nodes must provide ***protocol conversions*** [7]. However, the performance demands are related to an end-to-end connection and must be satisfied within the QOS requirement boundaries as described above. The TS related part of the object characteristics will be made available to all nodes affected by a connection. During the data transmission phase, the TS in each node checks whether the conditions can be met, otherwise it will execute some error handling functions. For example, if a network node determines that the transit delay option cannot be fulfilled during the transfer of an uncompressed video stream with real-time constraints, it will simply discard the incomin data packet to avoid if a network node determines that th transit delay option cannot be fulfilled, it will simply discard th incoming data packet to avoid useless transmission and proc essing in the network.

2.2 Multicast and Synchronization

Upcoming applications in the areas of conferencing as a pa of CSCW often assume a dynamically changing number of co operating partners. An adequate support of this mode of op eration requires ***group management support*** facilities. Her group communication facilities are provided in terms of appl cation support services. For CSCW applications it is importar to offer services that allow to address one, some or all grou members by unicast, multicast and broadcast techniques re spectively. Additionally, different reliability requirements hav to be fulfilled. This conveys to the so called reply semantic [14] which indicate whether the sender expects none, exactl one, some or all of its recipients to reply. Group managemer operation might be create, join, leave or query a group of par ticipants [6]. However, it should be noted that group commu nication techniques like multicast supporting applications ar not directly related to similar techniques supporting the T [2]. Nevertheless, the efficiency of the overall system might b increased in the case the TS provides casting services which al low a more direct mapping of application support requirement to TS services.

Often, a strong relationship between various media stream originated from a single processing node arises [26]. Conside an example where moving pictures and the related voice ar transmitted over the network and presented with the same re lationship in terms of timing at the receiving site as created a the sender's site. Whenever data is to be "recombined", we ca this type ***life synchronization***. Video conferences are typical ap plications which require life synchronization.

Another type of synchronization arises when independent in formation entities are combined for the purpose of joint infor mation presentation. This information is typically stored an not generated directly by a camera or microphone. Many ap plication using this synchronization expressed often by mean of "independent", "simultaneous" or "parallel" [23] belong t the category of retrieval applications according to CCIT Standard I.121 [4]. According to [18] we call this type ***syntheti synchronization***. Individual information entities might belon to or be used by several applications. In the context of data bases, document architectures or application programmin interfaces appropriate specification methods arise (see e.g. [1 22]).

In a distributed environment, synchronization may also involv many data streams originating from different locations [28] Note, that synchronization at the user interface is essential an many entities in between should provide adequate mechanisms Therefore, apart from the data storage and communicatio within the workstation, the upper layer communication service and transport level are important.

3. Media related Communication Model

From the application's view, the requested service from the communication system (CS) can be formulated in a quite simple fashion. It defines a media object along with a lis of recipients and assumes an adequate data transmission. As fa as the CS is concerned, according to the dynamic, heteroge

:ous conditions for the various types of media more infor-
iation is needed to achieve optimal services and to allow
ficient resource management. To fill the gap between the
irious raw services and options provided by the CS and the
pplications needs described above, we propose a object based
ommunication model for the definition and handling of media
ecific characteristics supported by the upper layer communi-
ition software.

he application abstracts from the CS services by defining or
sing predefined media related characteristics. For each type of
iedia, there is a media class describing them. A media stream
represented by an object of the respective media class. At
ommunication initialization, the object is made accessible to
ie CS. The CS will use the object for the connection man-
gement and mapping onto its services invoking object state
trieval methods. Apart from the QOS options about the re-
uested throughput, end-to-end delay, reliability criteria and
ynchronization there are other CS relevant options as part of
ie object contains information like flow control, resource res-
rvation, delay sensitivity and service match. The resource
servation parameter may define time periods and whether re-
ources must be allocated as a whole or if a partial allocation
an be done. The delay sensitivity expresses the degree of sen-
tivity to delay that can be tolerated by the application. A
ervice match option specifies if conditions are fix or if the CS
an take a "best effort" approach. If the system grants the ser-
ice specification, it will not be violated for an established
onnection.

Vithin the class specification, the actual communication rele-
ant parameters are defined. In a B-ISDN environment, for
xample, predefined media classes will exist for some often used
nedia like text, telephone quality 8 bit PCM coded audio and
ncompressed 140 Mbit/s video. The classes are arranged in a
nedia class hierarchy. Additional CS parameter combinations
nd media descriptions can be defined as new subclasses.

\ flat hierarchy can handle only a single medium communi-
ation properly, but often various media have to be combined
vithin a single application. To cover the arising issues of syn-
hronization of multiple objects, we have to extend our model
owards classes related to multiple media streams. For this
urpose we can use the "Compound Multimedia Object"
CMO) model very nicely [27] and extend it for the CS relevant
nformation. A CMO is a composition of multiple objects.
Iaving its own set of operations and control structures it con-
ains the definition of relations among its objects and oper-
itions. A CMO can be defined using basic object types or
ther compound object types. With the CMO model, multiple
nultimedia resources can be represented and managed within
he framework of a single object. The components of a CMO
nay be distributed in the network. With the CMO model we
iave the means to express the synchronization requirements
f several media streams for the CS.

Another very interesting and important aspect of the object
nodel is that we are able to support heterogeneous communi-
ation facilities transparently for the application. They are in-
lependent from the underlying network architecture since the
CS requirements are specified in a media type oriented fashion.
Depending on the progress in high speed networks we are able
o integrate this concept on top of new networks like FDDI,
DQDB, B-ISDN or others relatively easy.

4. Application Services of the Communication System

The upper layer services provided to the application should be
as simple as possible and transparent to networks and operating
systems. Multimedia applications may process multiple media
streams, the sources and sinks may be distributed in the net-
work. It is important that a media stream can conveniently be
defined with all its relevant attributes for storage, distribution
group management, communication, presentation and access
control. Another aspect is that a user may want to have con-
trol over a stream while it is being processed. Although there
may be different ways to tackle these issues like [16], we claim
that the object based model introduced in the previous chapte
fits very nicely.

4.1 Media Objects

Devices (a video display, a camera, an audio file, a video file
a loudspeaker, etc.) are viewed as typed objects and identifie
in programs by a handle. The type of an object determines it
interface, i.e., the supported set of operations. New object type
may be generated at any time. Besides the operations associate
with an object type is a list of attributes. It may be separate
in a variable number of groups; each group specifies the rele
vant attributes of a specific area, for different objects there may
be different groups. The object description can be used to gen
erate stubs for object creation and access, the attributes can b
passed to the lower layer components to perform the oper
ations.

In the following example, we will sketch an object type defi
nition and concentrate on the attributes specification. The at
tributes shown here should be considered as an illustration an
not as a complete specification. New attributes and/or nev
groups may be added as may be required. We define an objec
of type video with its set of attribute groups.

```
Multimedia object;

ATTRIBUTES:

 description:
   unique_id            = xyz123;
   user_name            = my_video;
   access_name          = root/videos/mv;
   object_class         = video;
   application_class    = interactive;

 version/date:
   version              = 1.2;
   creation_date        = 040190;
   modification_date    = 010191;

 managing:
   creator              = D. Duck;
   owner                = M. House;

 storage, input/output:
   device               = VCR;
   catalog              = filesystem;
   storage              = external;

 distribution:
   is_distributed       = maybe;
   distribution_option  = access control;
   recipients           = group;

 group management:
   group_control        = dynamic;
   casting              = unicast, multicast, broadcast;
   multicast_reply      = none, one, some, all;
   group_control_ops    = JOIN, LEAVE, QUERY;

 communication:
   type                 = isochronous;
```

```
  end-to-end delay    = 100 ms;
  jitter              = 10ms;
  bandwidth           = 100 Mbits/s;
  bit_error rate      = 10^-2;
  multicast           = yes;
  service match       = yes;

presentation:
  coding              = PAL;
  compression         = no;

access control:
  access              = owner, group;
  owner_operations    = ON, OFF, RECORD;
  group_operations    = PLAY, PAUSE, STOP, REWIND;
  reservation         = multiple_read;

user defined:
  alternate_name      = comic;
  status              = final_version;
...

ETHODS:
    ...
```

Example of a Video Object Definition

The *description* part maintains general information about the object. Each object has a unique identifier given automatically at creation time, a user name provided initially by the creator, an access name reflecting its full name within an composed object and the class the object belongs to. The application class denotes the application environment.

Version and date of an object and its creation and modification time are necessary to handle it in working environment. If data for a multimedia application is to be composed, contents of objects might change, but other characteristics remain. Only the version indicates the changes of data.

Managing information is necessary to indicate responsibilities for the object, i.e. where to get access rights and further information. If members of a group do have write access to a single object, the access right might be managed by the owner or other responsible for this object. Also the one currently holding the access right might be indicated.

The *storage, input/output* attributes describe the storage representation or I/O characteristics of the object. Here, the video data are stored on a VCR, the description of the video tape is kept within the filesystem. The VCR managing process knows more about the VCR itself, like the VCR type (VHS).

With the *distribution* attribute group we can express if the object itself is distributed (the VCR and the description may reside on distinct nodes). The object can be accessed confirming to the access control attributes and the recipient attribute. The object operations are distribution transparent. The recipients attribute determines that the number of recipients is restricted to a group.

In the *group management* section the relevant options for the group management can be specified. The group control attribute defines whether the number of group members is static or dynamic. With the casting attribute, we specify that the communication can be unicast, multicast and broadcast. The multicast_reply determines the reply semantics in terms of multicast communication as described earlier. The operations for group control are defined with the group_control_ops.

The *communication* attributes define the requested QOS for th transport service when transmitting objects of type video acros the network. We require support of multicast communicatio according to the group management attributes and an exac match of the service match options.

The *presentation* group options serve two aspects. First, the contain information about the object representation which ca be used by the applications. The second purpose is to suppo a presentation layer like function when transmitting object across the network. The video object on the VCR is a PA video stream. When the object will be transferred across a dig ital network, this information can be used by the system to in itiate a PAL-to-digital conversion first.

Objects in a distributed environment need to be protected suc as a process or user must obtain the right to perform operation on the object. The *access control* attributes can be used to de fine access rights onto a given object and specify additional re strictions like multiple read access. The video object in ou example may be accessed by the object owner and by member of a defined group. The operations are also divided in owne specific and group specific ones. A finer granularity of acces control can be achieved by an authorization and authenticatio subsystem.

User defined attributes might be reserved fields for some objec users to store their own object information necessary for the work. For example, if someone is searching certain informatio by browsing through a lexicon realized as a composed multi media object, he might wish to record the history of his searc within the object itself or to mark found information.

4.2 Communication Channels

Objects represent sources and sinks of multimedia data stream They are interconnected by objects representing *communicatio channels*. Multimedia data can be seen as messages which wi be routed by the channel from source to sink. The channe concept is similar to the UNIX pipe mechanism and the con nector mechanism as described in [16].

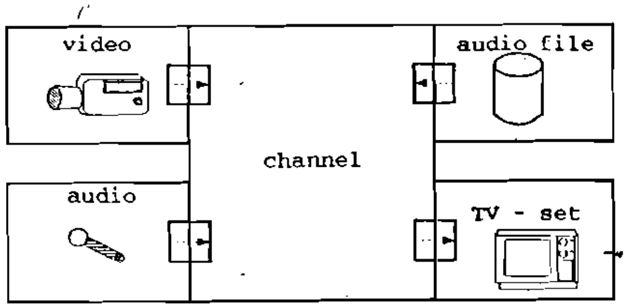

Figure 1. Example of a Communication Channel

In Figure 1, a scenario of remote video and audio with loca playback is given. At the application level, the user sees fiv components, the two remote sources camera and microphone the two local sinks audio file and TV-set and the communi

:ation channel connecting these objects. The channel defi-
iition contains the type of objects to be connected as source
›r sink.

n the attributes specification of the channel object, the re-
ationship of the different objects are specified in the synchro-
iization group. Since one or more sources and sinks can be
:onnected to a channel, we also need a way to denote the type
›f multicasting (1-to-1, 1-to-M, N-to-M). It is done by speci-
ying the connect points in the channel's definition, the actual
›inding between source(s) and sink(s) via the channel takes
›lace at runtime via the connect operation. The number of
›bjects connected to a channel may vary during the channel's
ifetime. Sources and sinks may connect and/or disconnect dy-
iamically. In order to get a multimedia data stream from a
›ource to a sink, the application will invoke a connect opera-
ion and initiate the data transfer. For example, the video
:amera and the TV-set will be connected to the channel as
›ource and sink, then the operation start_camera will start the
lata transfer.

For the channel object, there is also an object type definition
ıs we have already seen in the previous example. In addition,
he channel object has a specification for the connection points.
As an example, we have specified a channel object with its at-
tribute groups synchronization and access control according to the scenario in Figure 1 on page 4. The synchronization attributes are very important for the channel object. They define the synchronization relationships between the various media streams and as set of out-of-sync event handling operations. The synchronization attributes will also be used by the transport service in order to provide synchronized data transfer.

```
Multimedia object;

CONNECT-POINTS:

  video_source: video;
  audio_source: audio;
  video_sink  : video[N];
  audio_sink  : audio[N];

ATTRIBUTES:

  description:
     ...

  version/date:
     ...

  managing:
     ...

  synchronization:
     sync audio with video;
     out-of-sync audio: ...;
     out-of-sync video: ...;

  access control:
     access = owner, group;
     owner_operations = CREATE, DELETE;
     group_operations = CONNECT, INQUIRE, DISCONNECT;
     access_mode      = 1-to-many;

METHODS:
     create;
     delete;
     (dis)connect_source;
     (dis)connect_sink;
     ...
```

Example of a Channel Object Definition

The channel concept provides an abstraction to the applic
tions in order to process multiple media streams within tl
context of a single object. The channel may be mapped ont
several TS connections depending on the network architectur
When objects connect to a channel, the channel will know the
attributes. The channel will check the attributes of sources ar
sinks for consistency and will report errors to the applicatio
or perform error recovery functions respectively. For exampl
if the video camera uses the PAL coding scheme but the TV-s
is of type NTSC, the channel will either report an error or wi
route the video stream through a converter if possible.

5. The DiME Project

The DiME (*Di*stributed *M*ultimedia *E*nvironment) projec
provides a suitable programming support offering commun
cation services for distributed multimedia applications.

In order to explore the challenges of multimedia commun
cations our first goal was to set-up a communication laborator
with interconnected multimedia workstations [1] similar to th
Integrated Media Architecture Laboratory (IMAL) conceive
at Bellcore in Red Bank [19] and the the Muse and Pygmalio
system of MIT's Project Athena project [13; 5; 20]. Th
multimedia equipment comprises plug-in boards (AVC
M-MOTION and DVI) and external devices like audio/vide
switches, VCR, CD-player, optical memory, cameras, moni
tors, microphones and loudspeakers. With this off-the-shel
equipment controlled by conventional workstations, we are i
the position to enable full-motion video display, frame grab
bing, audio and video storage, processing, presentation an
compression.

The DiME system structure (see Figure 2) was conceived to
wards hiding hardware details to software components by th
provision of device servers [25]. Additional basic services for th
configuration and supervision of DiME components are als
part of the prototype. For testing and demonstration purpose
we developed local and distributed control applications runnin
under the Presentation Manager of OS/2 for all devices. A
control interface for a CD audio player has been ported to X
windows running under AIX as a first distributed heteroge
neous experiment.

With the so far completed first experiments with DiME

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[1] To our view a multimedia workstation allows for manipulation, presentation, storage and communication of various media including audio and video.

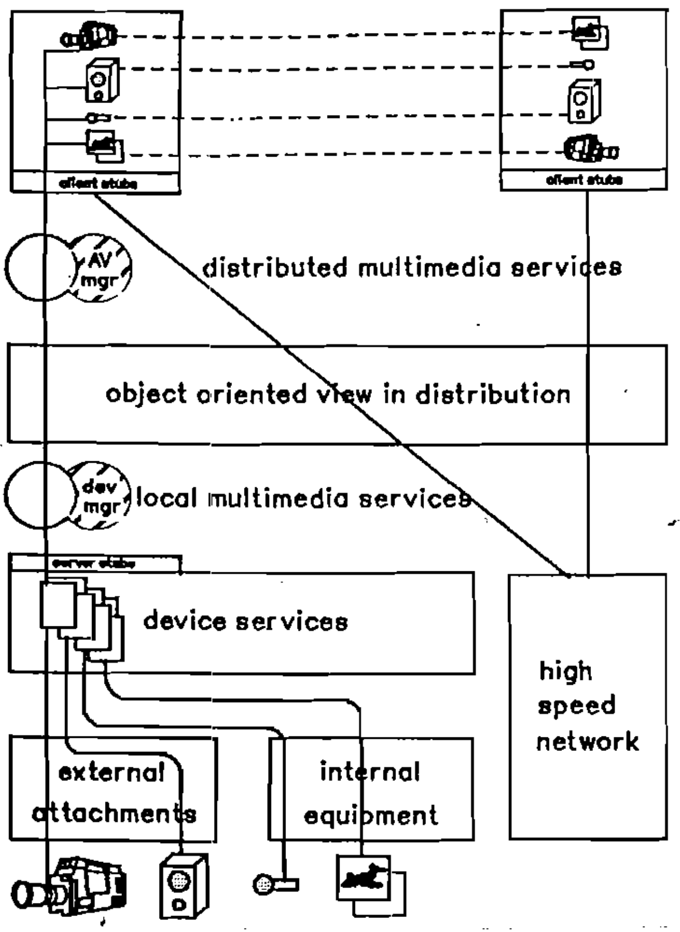

Figure 2. The DiME System Structure

- based on our knowledge of communications and distribution we gained experience in the multimedia area and
- demonstrated the possibility to process the whole range of multimedia data with available equipment in a laboratory today.

5. Conclusion

We are now in the position to design a lower layer communication interface with upper layer multimedia oriented services like those presented in this paper. Communication support for distributed multimedia systems affects all layers of the communication architecture. At the lower layers, we need high speed networks with new adequate transport system. Isochronous and asynchronous data transmission properties are required; the quality of service requirements depend on the media object to be transferred. In addition, motivated by new application scenarios in the CSCW area, the transport service has to provide functionality to support group management and synchronization on top. Higher layers must supply communication services for efficient application development. Distribution, network architectures and host environments should be transparent.

The incorporation of various media, with distinct properties, into advanced applications requires a working framework specified on an abstract level. The object based approach with grouped lists of attributes is the first step in this direction. The definition of the communication services from the application's viewpoint, their mapping from upper layer communication services onto the transport system and their integration into a comprehensive communication architecture will be the future challenge.

The future work at the IBM ENC concerning multimedia moves towards this direction with closely related activities. Projects deal a transport system including real-time isochronous data communication for the various types of media within a high speed network environment. In another project, we are working on the upper layer communication services including group management, synchronization, distribution, access control and presentation. Other activities cover the structuring of complex documents including audio and video conforming to existing document architectures and standards and the access of such documents in a distributed environment.

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